The SciDAC Visualization and Analytics Center for Enabling Technology

The VACET Research Portfolio

Ken Joy, UC Davis, co-PI

Overview

- Review of the VACET research portfolio
- Relationship to petascale challenges in the visualization field
- Future directions for research

VACET Research

The VACET research agenda is driven primarily by science stakeholder needs.

- Each research contribution can be traced to a specific science stakeholder problem.
- We attempt to implement our research within one of our deployment vehicles
  - So that our tools can be utilized by our stakeholders
  - and we can get feedback

What are the research challenges?

- Challenges in large-scale data analysis that impact our science stakeholders
- Challenges within the visualization field to develop techniques that impact data analysis
- Challenges of Petascale

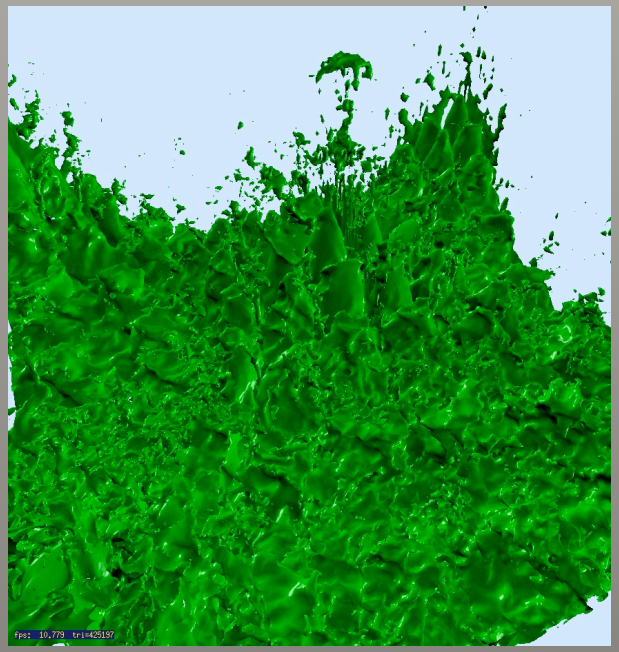
Challenges for Petascale Visualization

- Data/Information is growing along four fundamental axes
  - Spatial
  - Complexity
  - Temporal
  - Ensembles

And different questions must be answered depending on "your location" in this four-dimensional space.

Challenges for Petascale Visualization

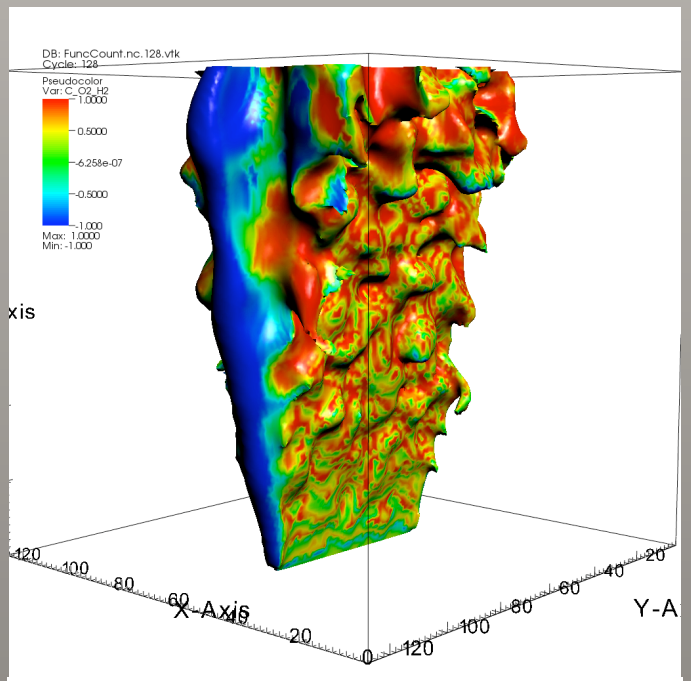
- Spatial Growth
  - Growth in grid size, and in grid complexity



Interactive fly-through of data sets containing ~500 million triangles, rendered at interactive rates.

Challenges for Petascale Visualization

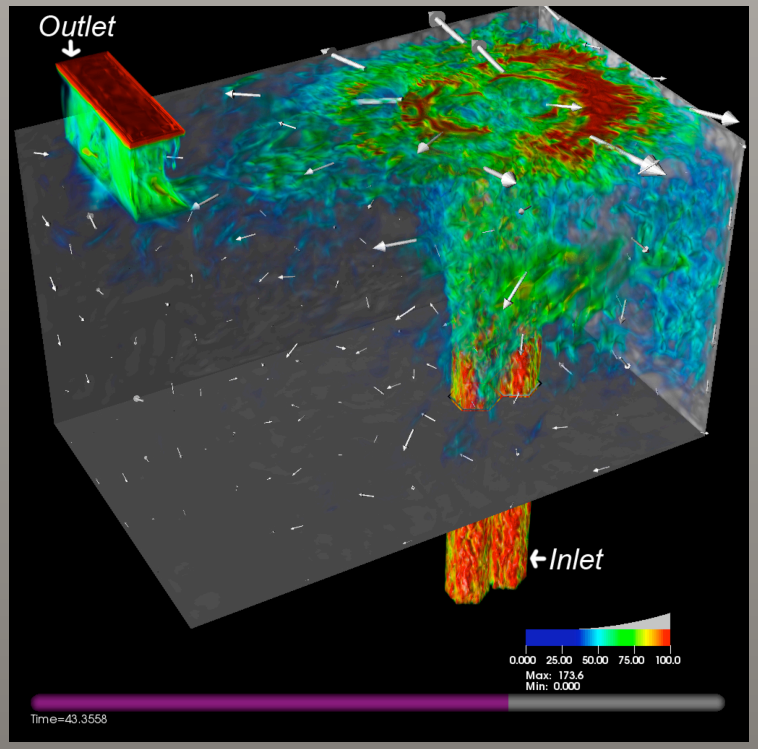
- Complexity
  - Vertices contain arrays of
    - Scalar Values
    - Vector Values
    - Tensor Values
    - Functions
    - Distributions
    - …
  - Cells contain
    - Volume Fractions
    - Distributions
    - …



Isosurfaces of temperature visualized from a V-flame data set, where each data element contains 38 variables. The colors correspond to the correlation between water and methane in the simulation.

Challenges for Petascale Visualization

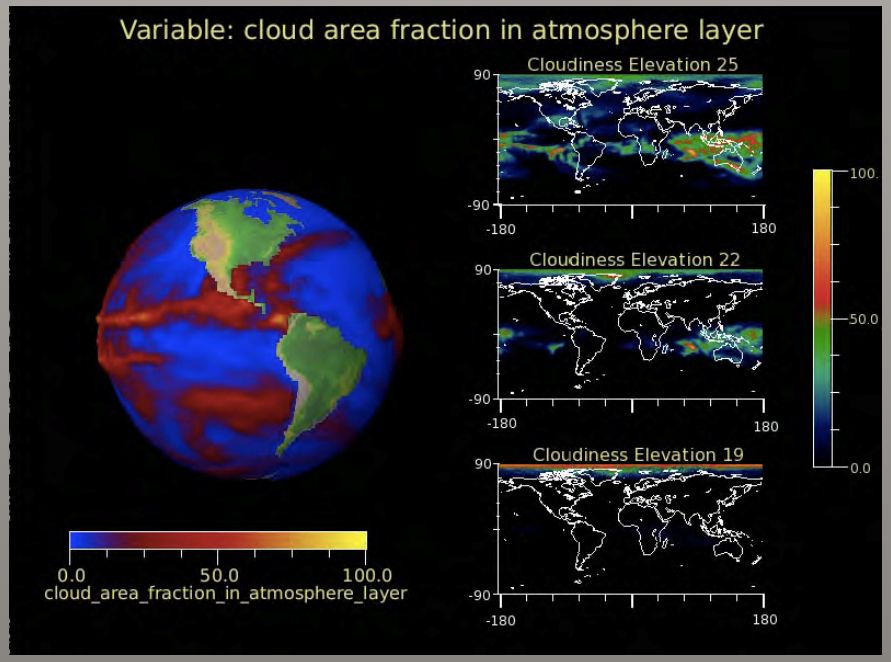
- Temporal Growth
  - Analysis and visualization in the temporal domain is “highly understudied” -- because it’s difficult



A thermal hydraulics simulation. Water enters a box through two inlets and exits through a single outlet. The mesh has 23,607,318 points and there are over 3600 time slices, for a total of 85 billion data points per variable.

Challenges for Petascale Visualization

- Growth of “Ensembles”
  - Researchers are performing parameter studies, where parameters are varied slightly and throughout several simulation runs.



To help estimate climate change, scientists perform ensemble runs, which consist of many runs of several numerical models using perturbations of input parameters and initial conditions. These ensemble runs produce massive amounts of data and give rise to the challenge to our team

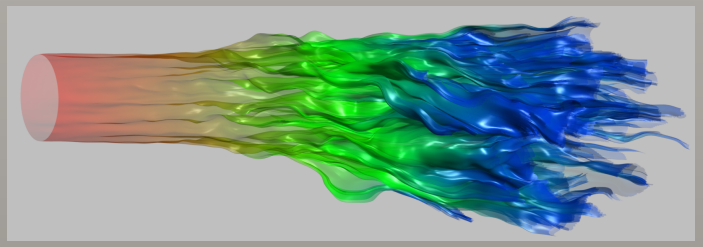
Field-Leading Research

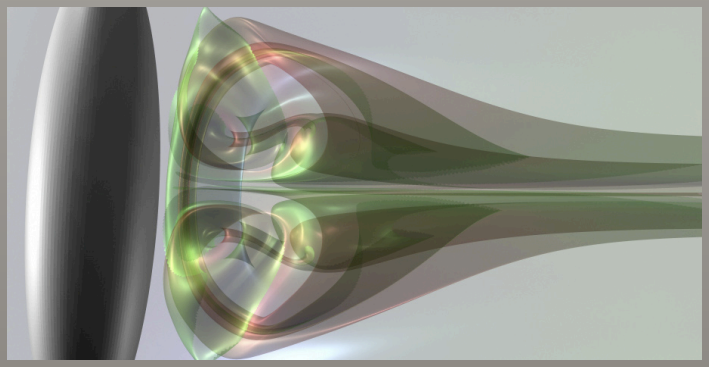
- VACET research has contributed to a variety of stakeholder projects, impacting all challenge areas of visualization

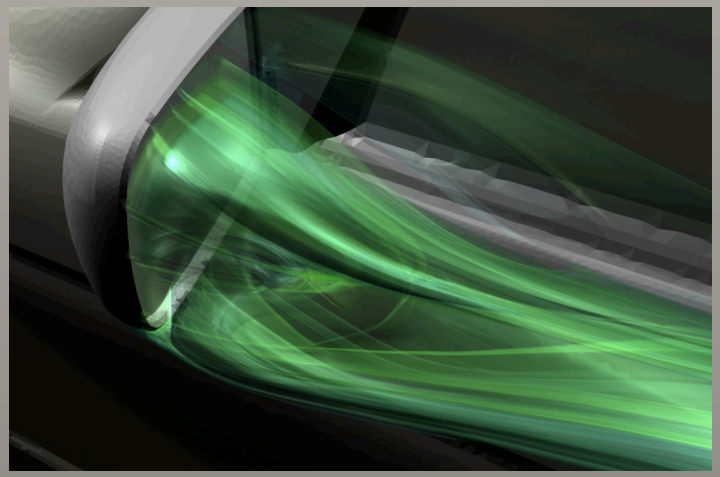
- Highlights…
  - (Note: Most of this information is in the two-pagers, submitted with the review document.)

Streamlines and Stream Surfaces

- VACET researchers lead the efforts to visualize stream surfaces in 3-dimensional flows

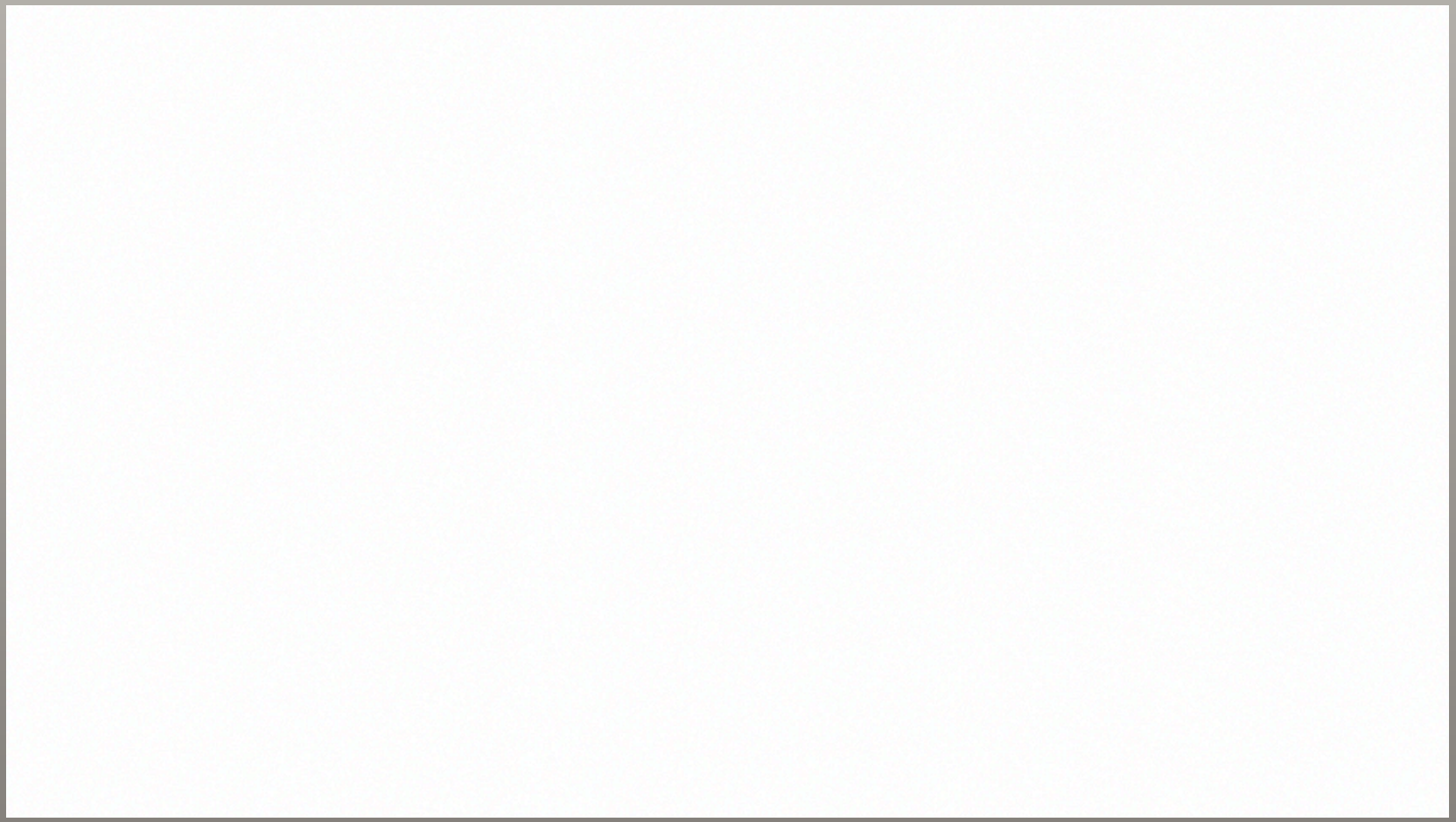




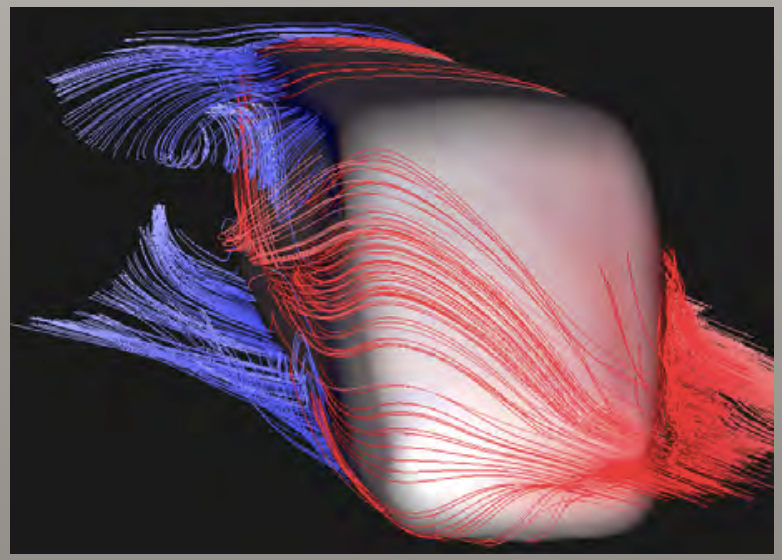


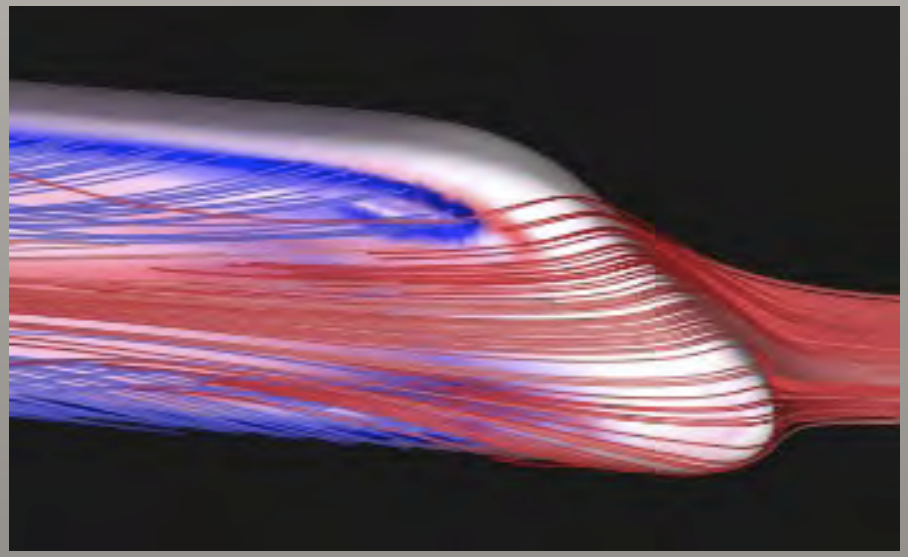
Turbulence is of interest to most scientists studying flow. However, it is also the characteristic that induces significant error in visualization algorithms. VACET researchers have developed new adaptive methods that accurately render stream surfaces, creating new analysis tools for researchers.

Streamlines and Stream Surfaces



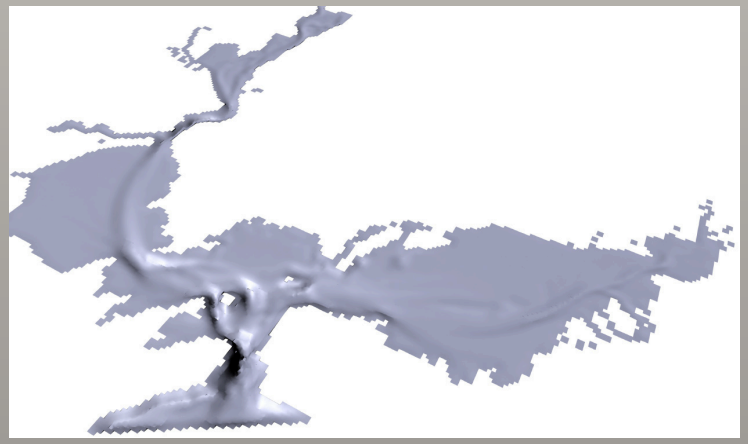
Streamlines and Stream Surfaces

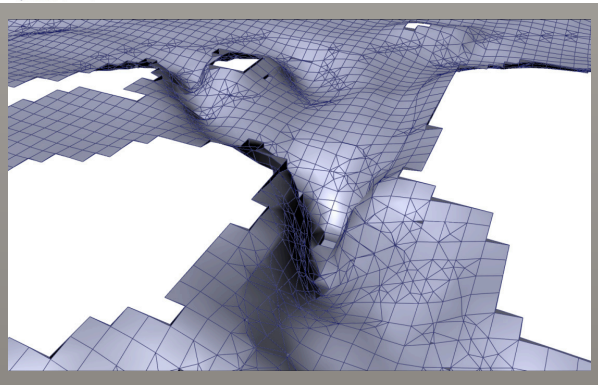




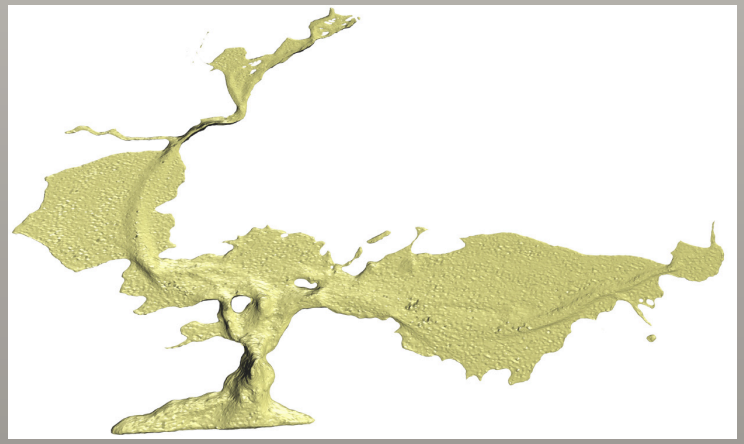
Lagrangian (FTLE) visualization of the flow of air around the nose of a train reveals where sheets of air detach and reattach on the side of the train (blue corresponds to detachment, and red indicates re-attachment). This kind of analysis reveals indirect traces of large vortices forming close to the side of the train, and their study is important to determine the stability of the train at high speeds

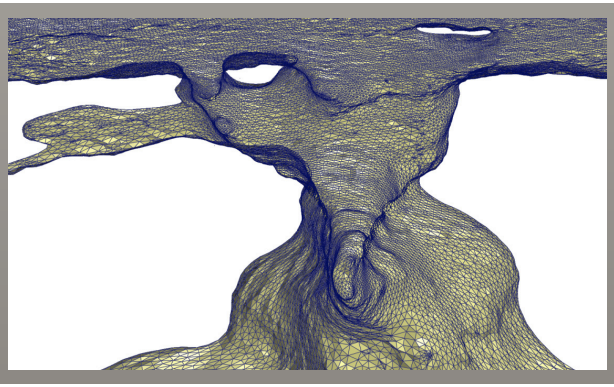
Embedded Boundary/Material Interfaces





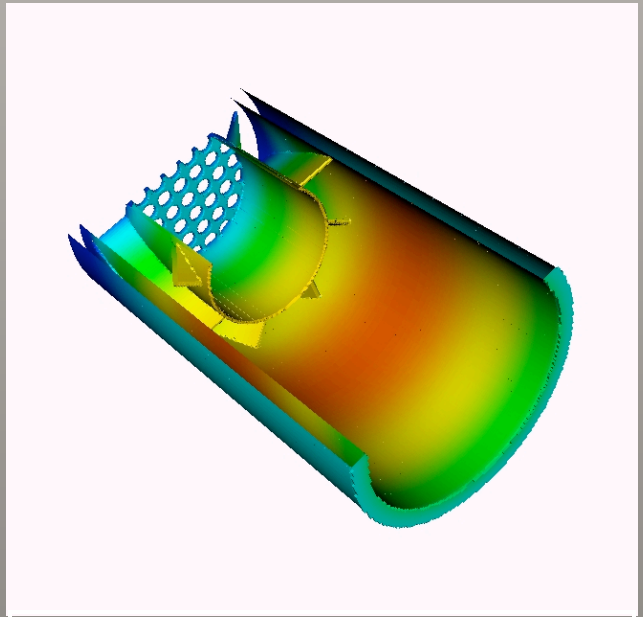
Reconstructions of an embedded boundary (EB) representation of bathymetry – or underwater depth – data from the San Francisco Bay. Embedded boundary reconstructed using existing methods.



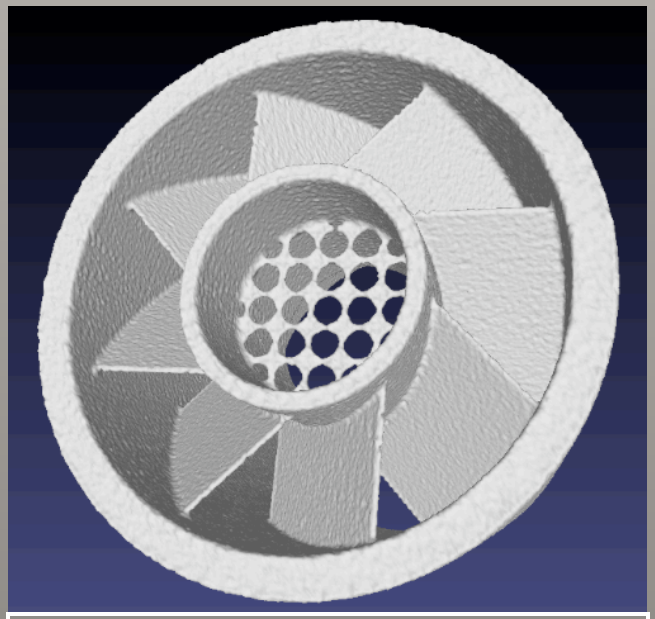


Reconstructions of an embedded boundary (EB) representation of bathymetry – or underwater depth – data from the San Francisco Bay. Embedded boundary reconstructed new active contour methods.

Embedded Boundary/Material Interfaces

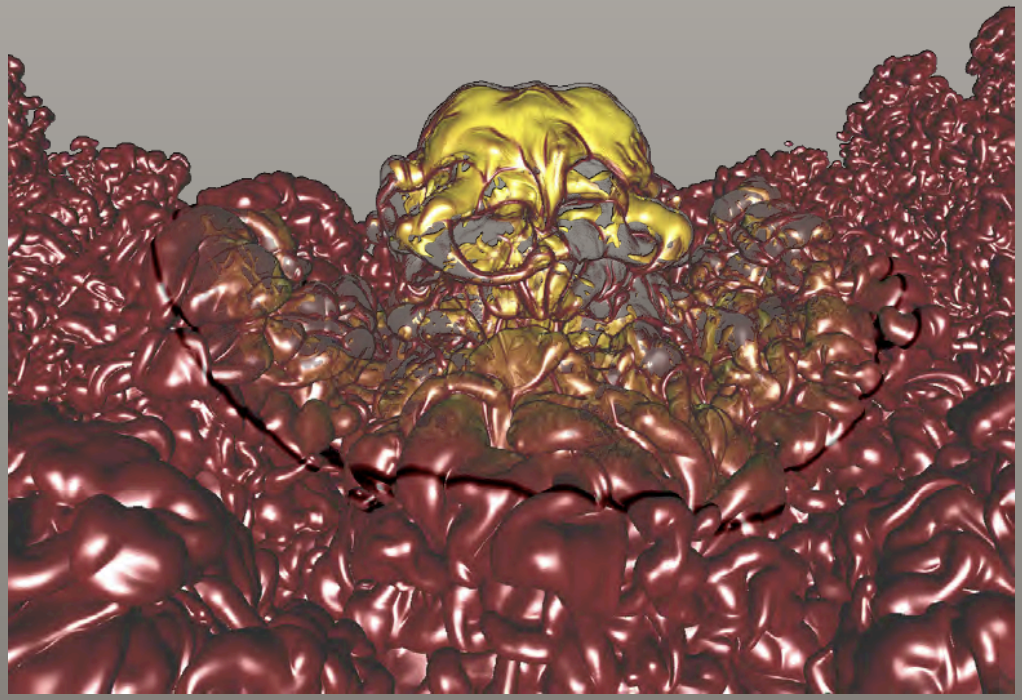


Cross section of a “swirler” (Courtesy of APDEC). This was used as a test case, developing volume fractions in a uniform grid.



Embedded boundary reconstruction of the swirler.

Hardware Accelerated Volume Rendering

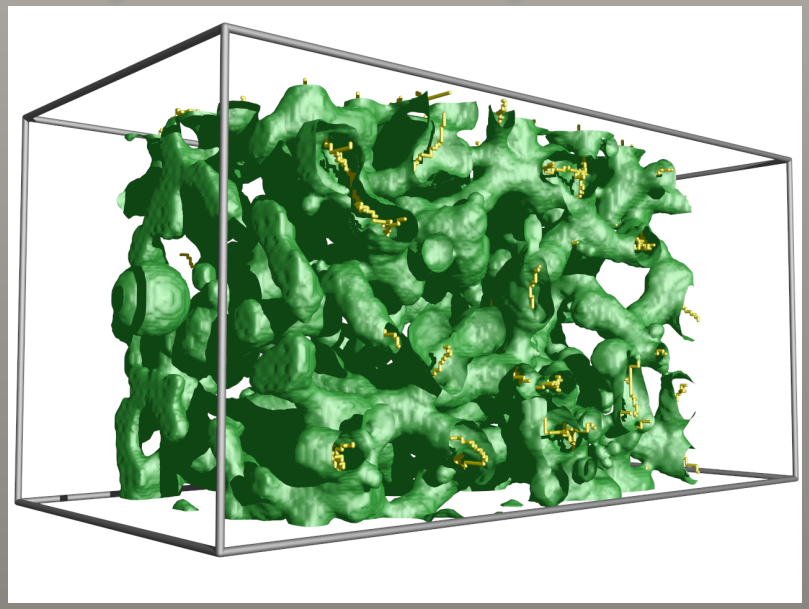


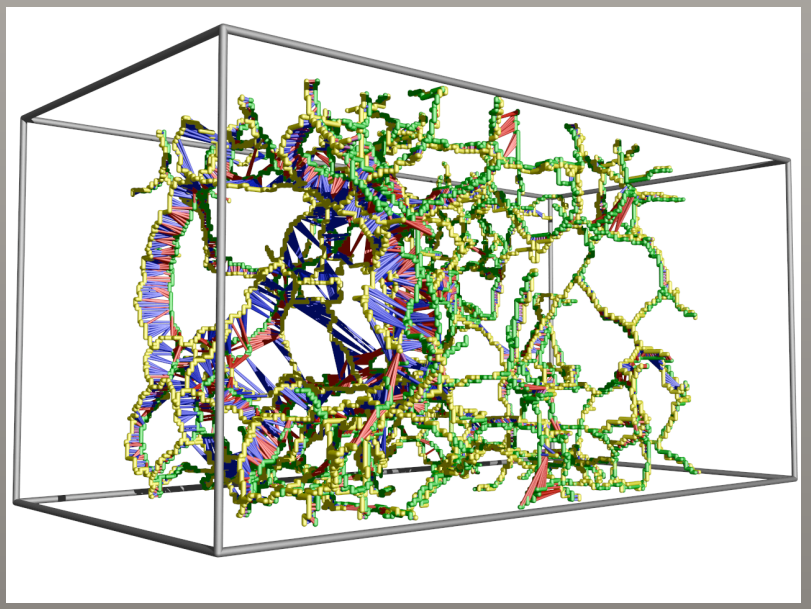
The “clear view” rendering mode of Tuvok, illustrated on the output of a Richtmeyer-Meshkov simulation.

These methods will be discussed in the Tuvok demonstration later.

Topological Analysis

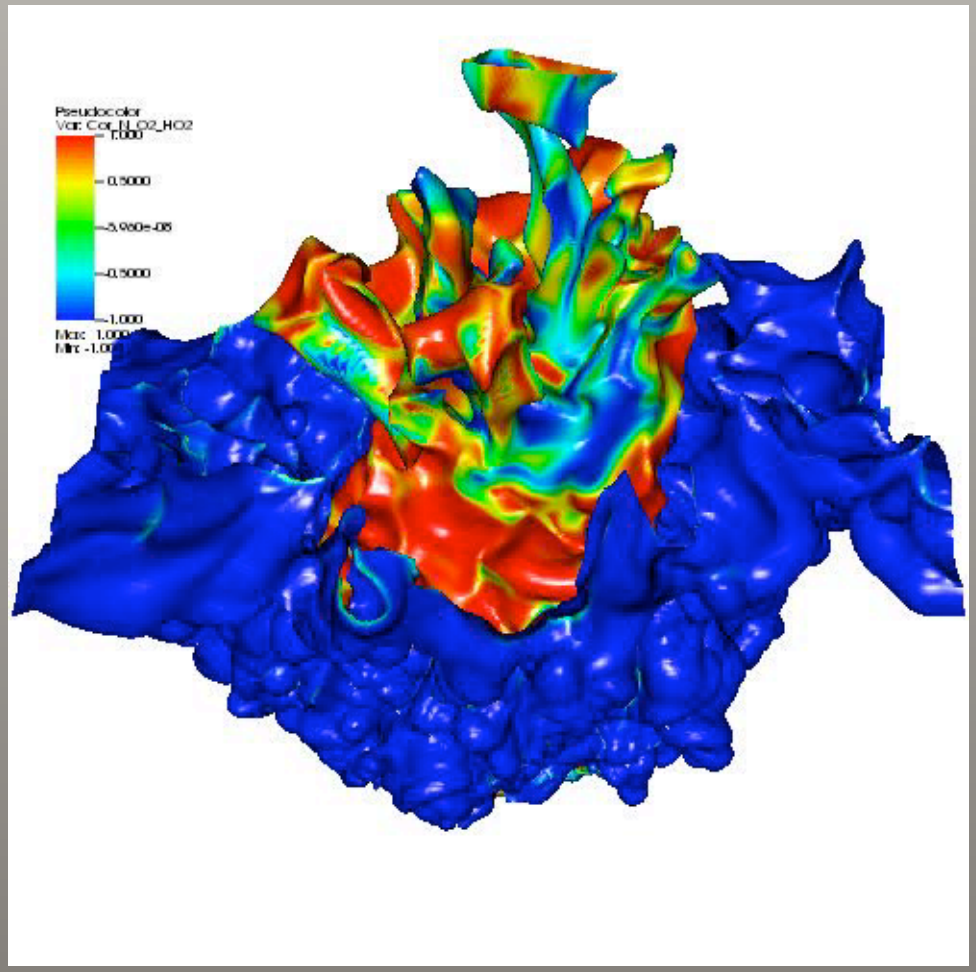
- The VACET team is the world leader in the use of topological methods in visualization and analysis (Valerio's Talk)





A volume rendering of the impact of the ball entering the porous solid. Using topology methods allow us to compare the core structures of the solid when deformed by the projectile.

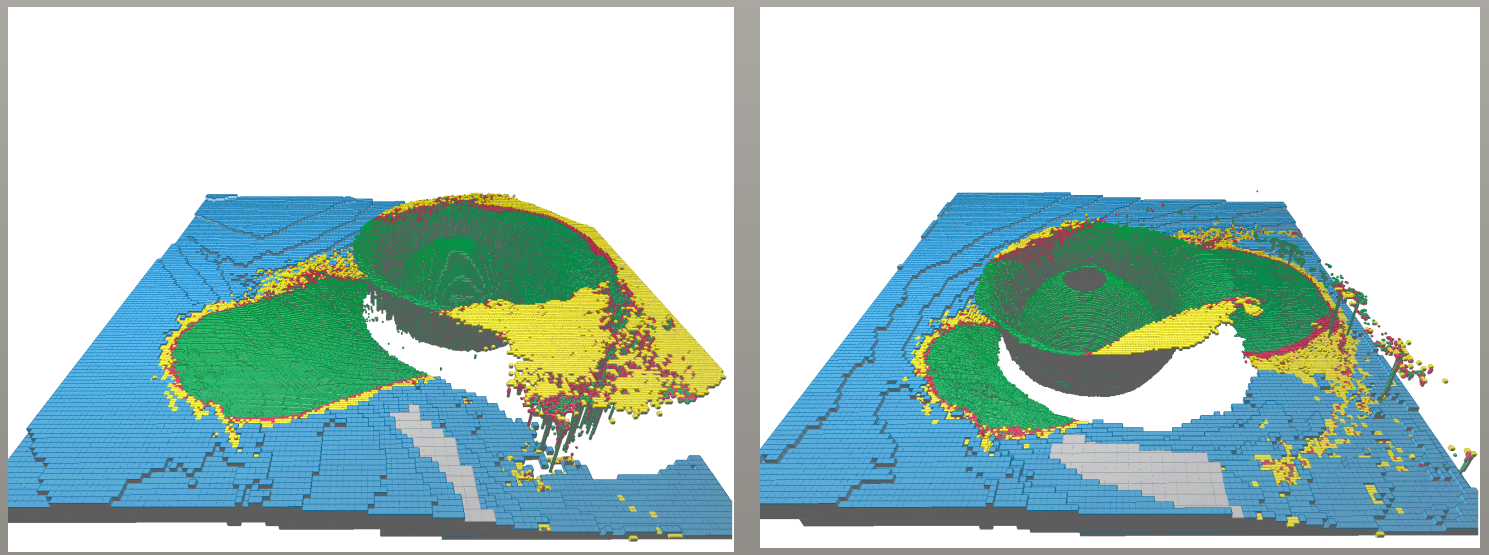
Variable Interactions in Multi-Dimensional Data



Isosurfaces of H2O2 in a hydrogen flame are rendered at increasing concentrations and colored with the correlation field constructed from the variables O2 and HO2.

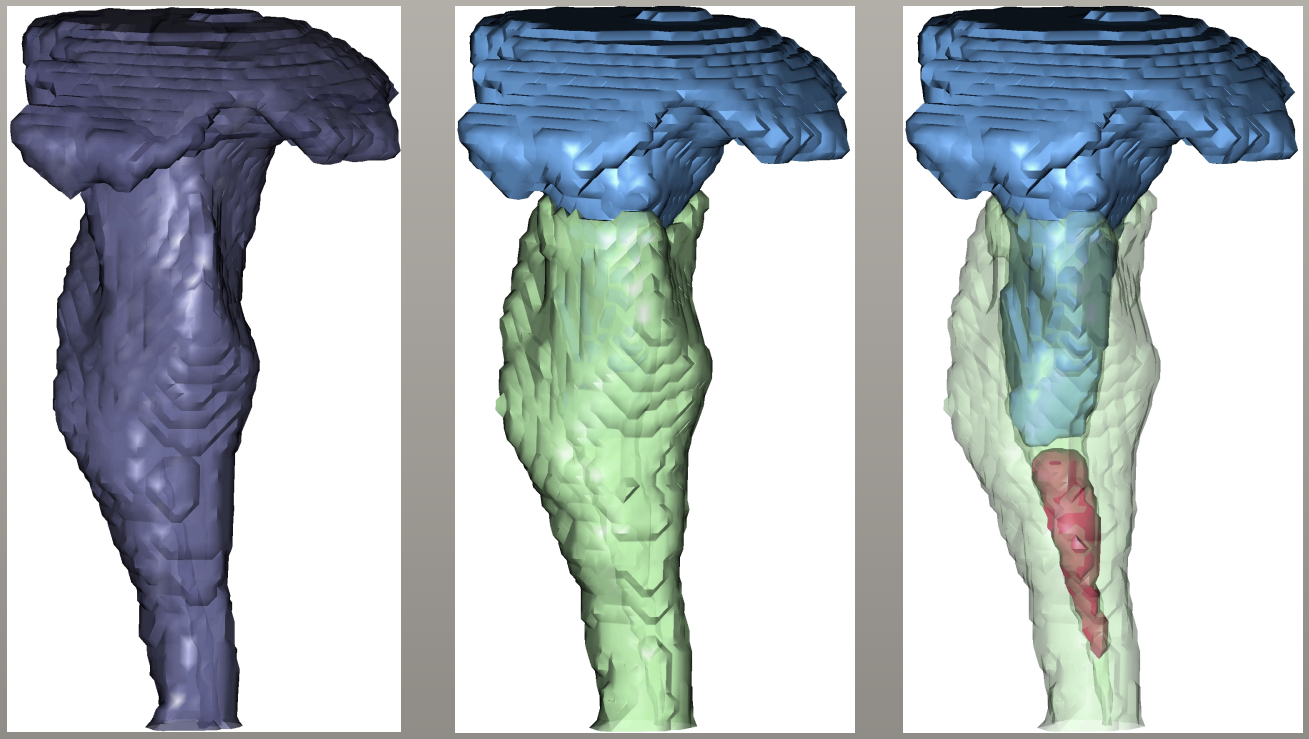
Query-Driven Visualization

- VACET researchers have led the efforts in query-driven visualization



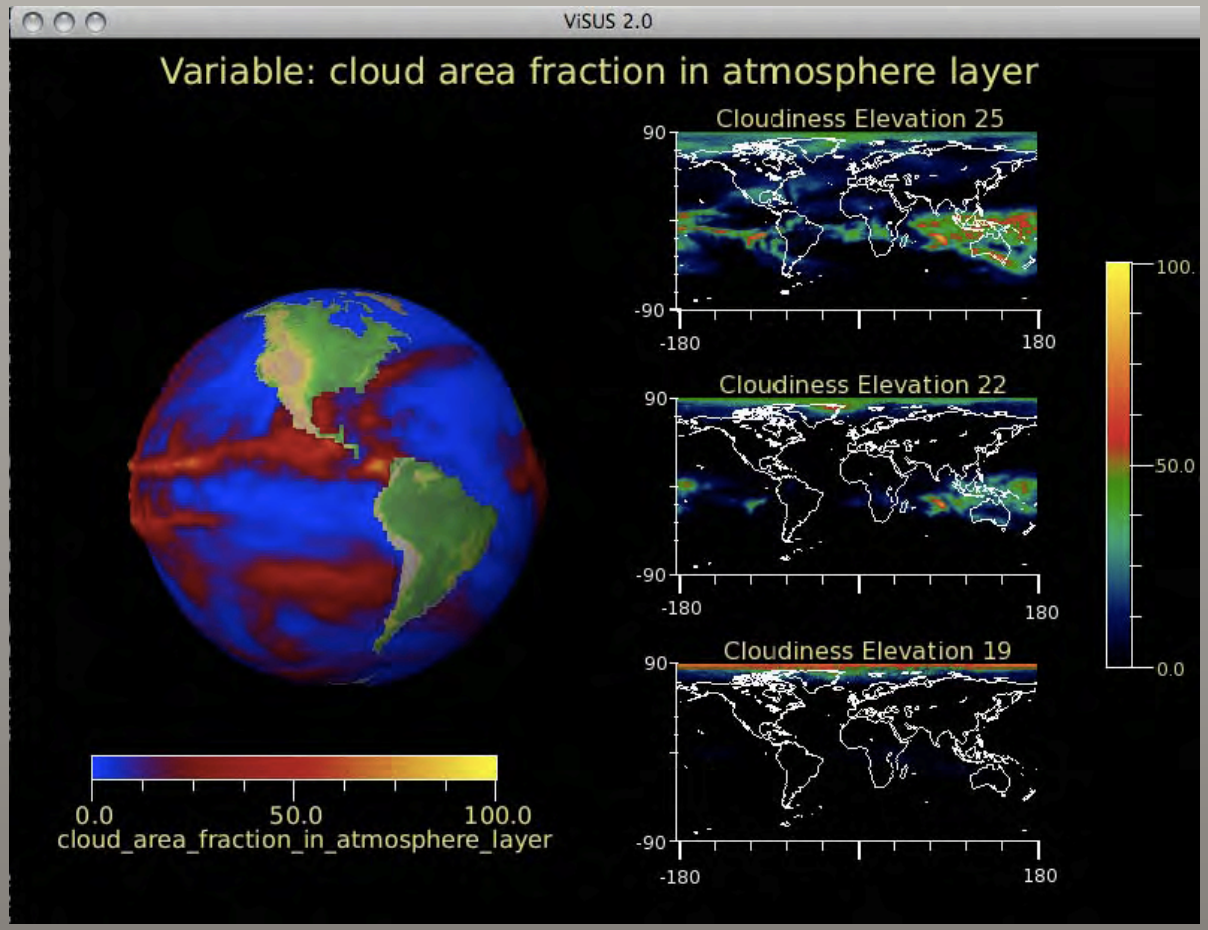
Visualization from a hurricane simulation that utilizes query methods. Researchers can directly query the data set, using simple query methods, which allows the visualization method to work on only a limited portion of the data. Quick query methods have been ported to the GPU to enable real-time interaction with large-scale data.

Query-Driven Visualization



New methods have been developed to allow one to examine the structure of a query's result. The left image is the minimum distribution surface of a query that extracts the core of the hurricane. The middle and right image segments the variables within the query solution space. These methods allow a researcher to modify queries to obtain better data.

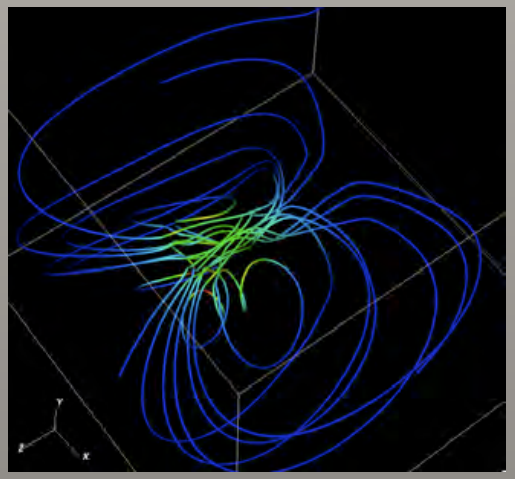
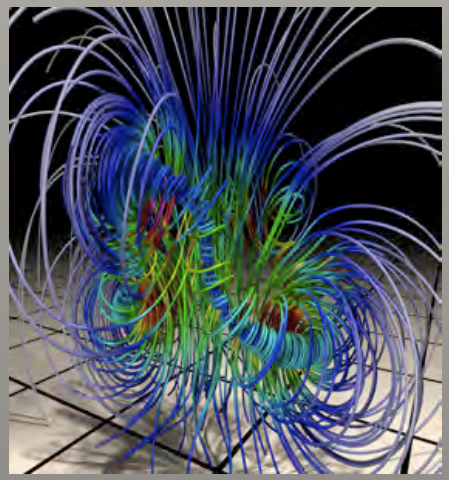
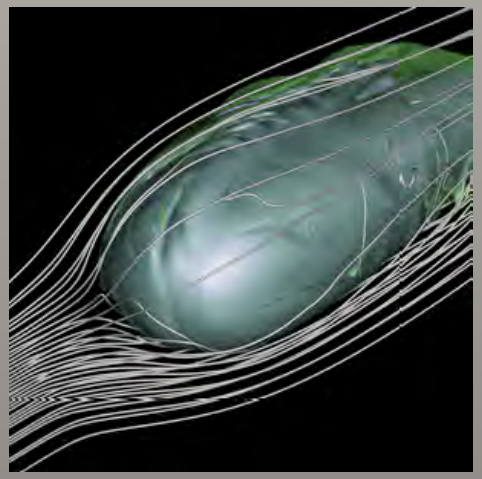
Uncertainty and Ensembles of Data



Uncertainty quantification within CDAT. We provide the user with multiple views for data exploration and analysis. This lets the user investigate multiple variables simultaneously, as well as understand the uncertainty of a single variable.

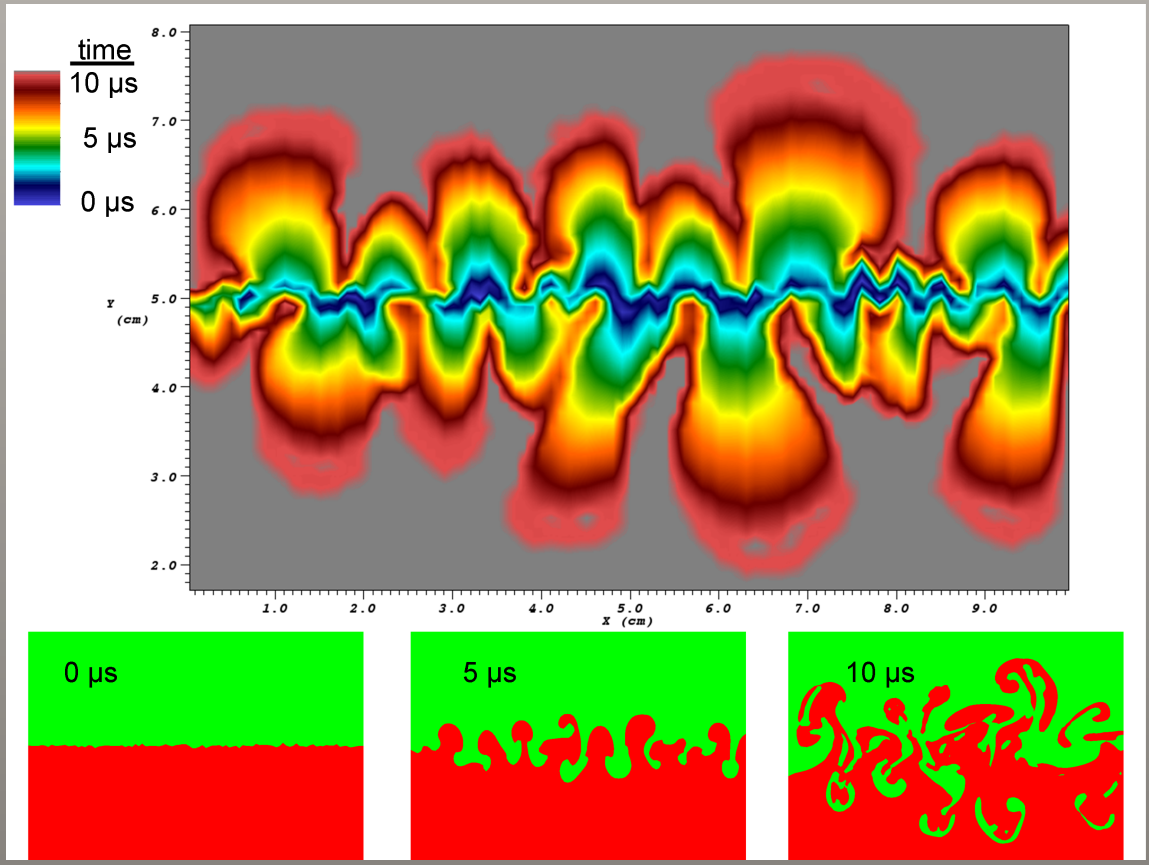
AMR Techniques

- VACET researchers have a number of projects related to AMR and visualization

New methods for streamline generation in AMR data sets have been developed that minimize the error of “naïve” algorithms when crossing AMR boundaries

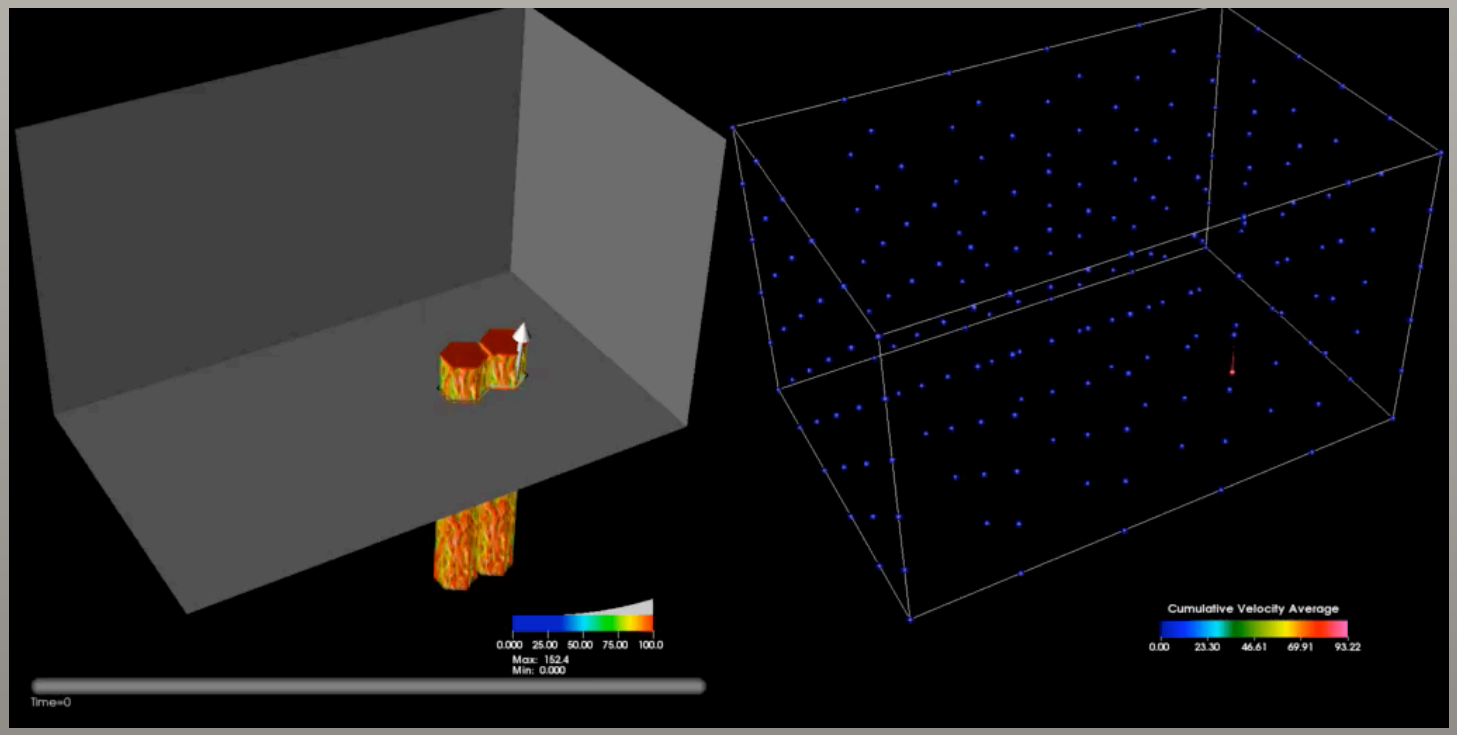
Multi-temporal Visualization



Multi-temporal visualization, summary visualizations of time-varying data sets has been an unreachable problem, due to the difficulty in reviewing all times slices of large-scale data sets. VACET researchers have now implemented this capability into VisIt.

This shows output from a Raleigh-Taylor simulation, where the color indicates the time at which mixing has occurred in the simulation.

Multi-temporal Visualization



A thermal hydraulics simulation, the mesh has 23,607,318 points and there are over 3600 time slices, for a total of 85 billion data points per variable. Water enters the box from two inlets at the bottom, and exits at the top. The multi-temporal visualization, being constructed at the right shows glyphs that represent flow magnitude.

Summary of Research Accomplishments

- The VACET research agenda is driven primarily by science stakeholder needs.
- Each research contribution can be traced to a specific science stakeholder problem.
- VACET Research has contributed to the solution of petascale visualization problems in all four axes
  - Spatial
  - Complexity
  - Temporal
  - Ensemble

Results of our Efforts

- Publications
  - 70+ Journal Publications
  - 30+ Conference Publications
  - 30+ Articles Books, Invited, and Posters

20+ papers submitted to the IEEE Visualization Conference on March 31, 2009

Results of our Efforts

- Awards
  - Video Awards
  - Best Paper Awards
  - NVIDIA Center of Excellence
  - Covers

Results of our Efforts

- Professional Service
  - Conference Chair (9)
    - Including top conferences in our field
  - Conference Program Committees (60)
  - Technical Reviewer (many)
  - Advisory Boards and National Committees (14)
    - IKS Review Board, LANL
    - Fundamental and Computational Science Committee, PNNL
    - NSF-CRA Computing Community Consortium

Results of our Efforts

- Outreach
  - Presentations (67+)
  - Tutorials (5)
  - Workshops (17)

PPPL VisIt Tutorial

Conclusions

- VACET has developed a vast research portfolio over the past 2 ½ years
- We have impacted a number of projects for our stakeholders
- We have addressed the petascale problems in visualization in all four impact areas

Future Work

- There is a lot to do…
  - Applying visualization methods to AMR
  - Uncertainty Quantification
  - Parallel Flow Visualization
  - Multi-dimensional techniques
  - FTLE flow methods
  - Deployment of our current and future research
  - …
  - and, of course, contributing new tools for our scientific stakeholders.

VACET

Thank You

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www.vacet.org

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